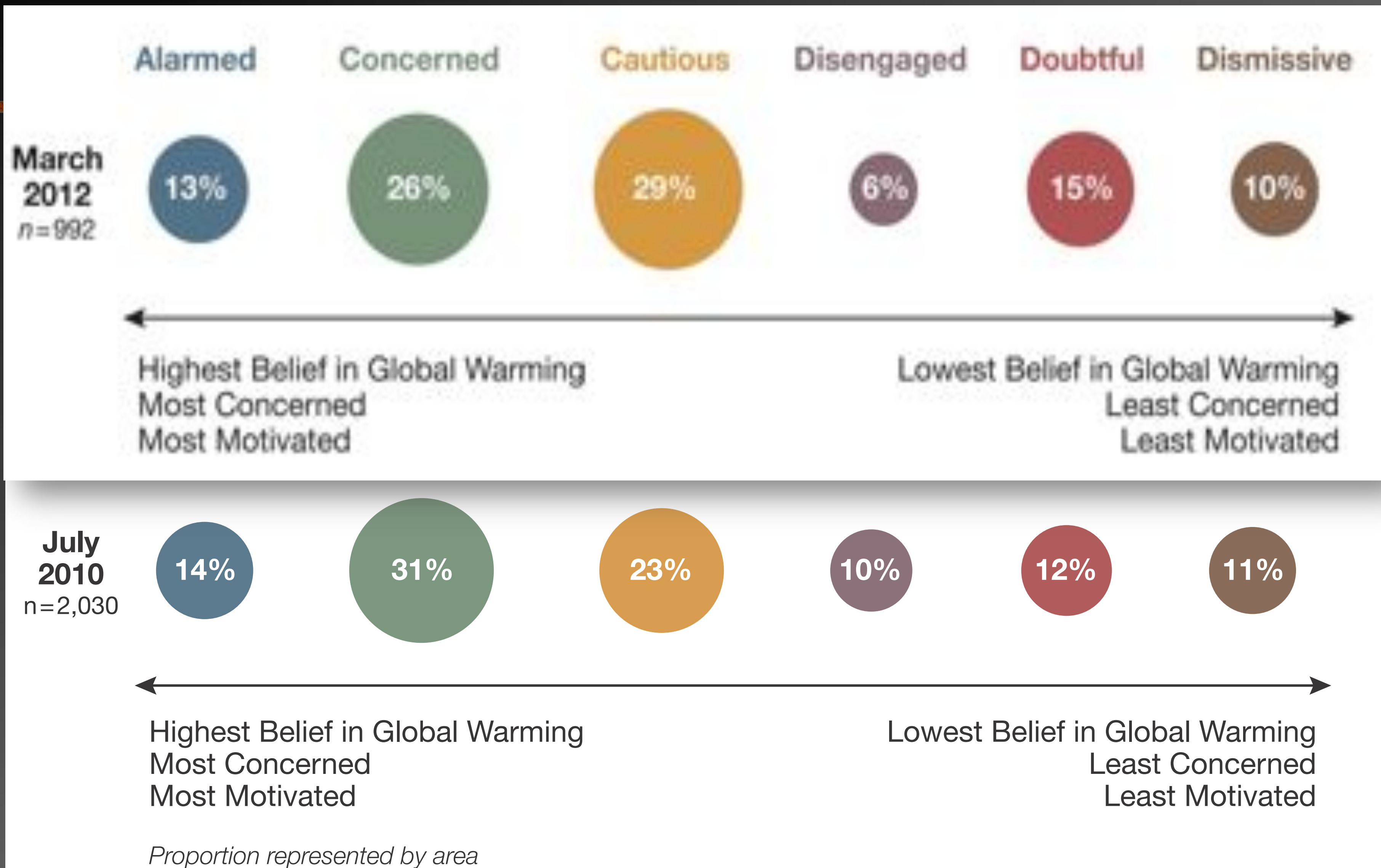
Global change: Scientific understanding and challenges for the future

KBS GK12 program *3 Oct 2012* *Steve Hamilton*

Global change, climate change, global warming?

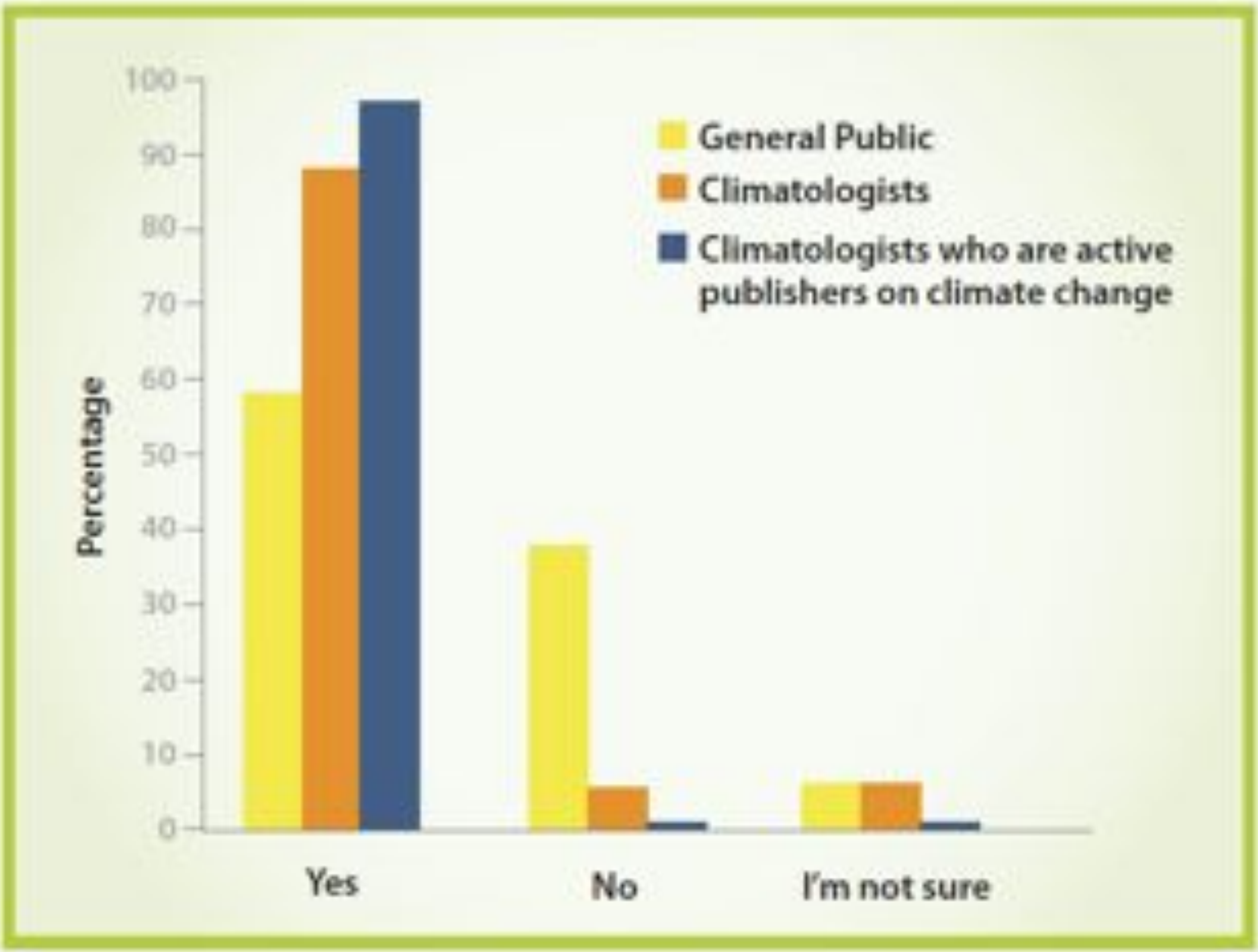
- Warming is the greatest driver of global change
  - But warming will not happen everywhere
- Many other climate changes expected:
  - Hydrological cycle
  - Extreme weather
- Effects extend throughout Earth system:
  - Less snow and ice
  - Ocean acidification by carbon dioxide

Do people understand the challenge?



Source: Yale Project on Climate Change Communication

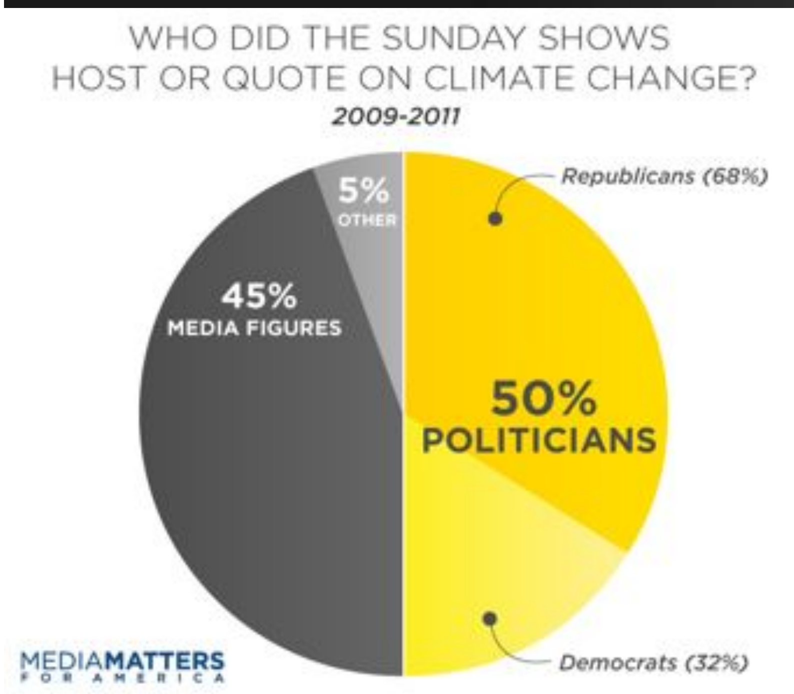
Scientific consensus vs. public confusion

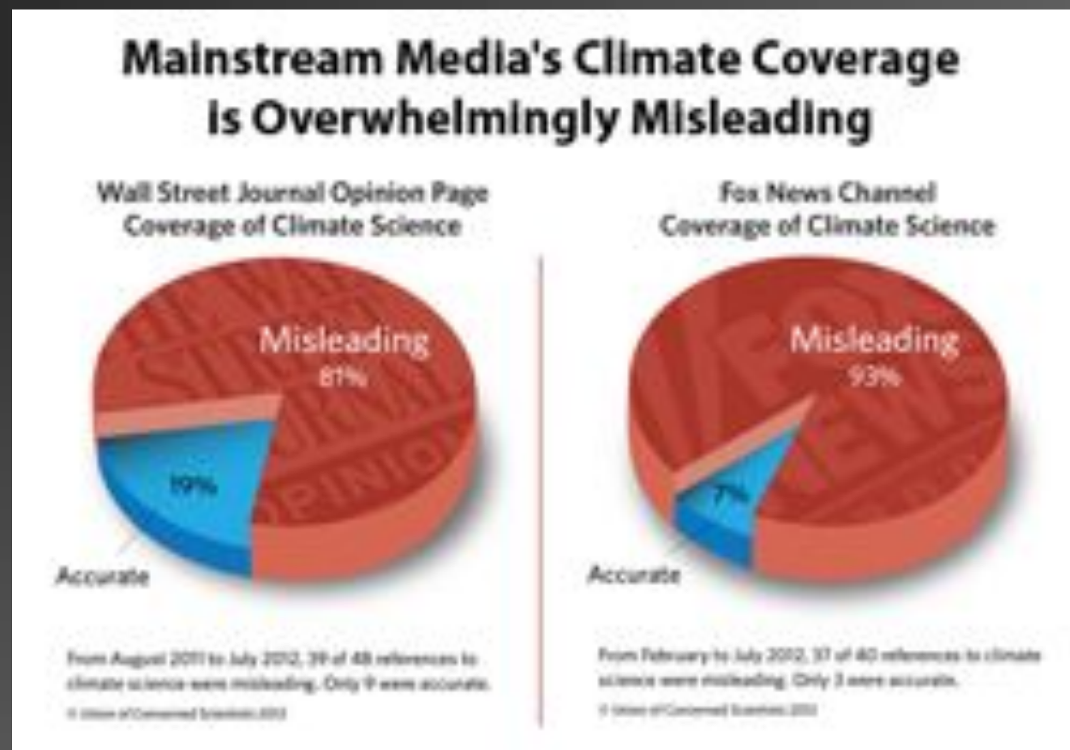


Are Humans Changing the Temperature of the Earth?
A recent study asked this question of the public, of climate scientists who don't publish many papers, and of those who do.

From "Twenty questions and answers about climate change" (Sally Ride Science and Climate Central, 2010)

Scientists are often not even in the public discourse on global change





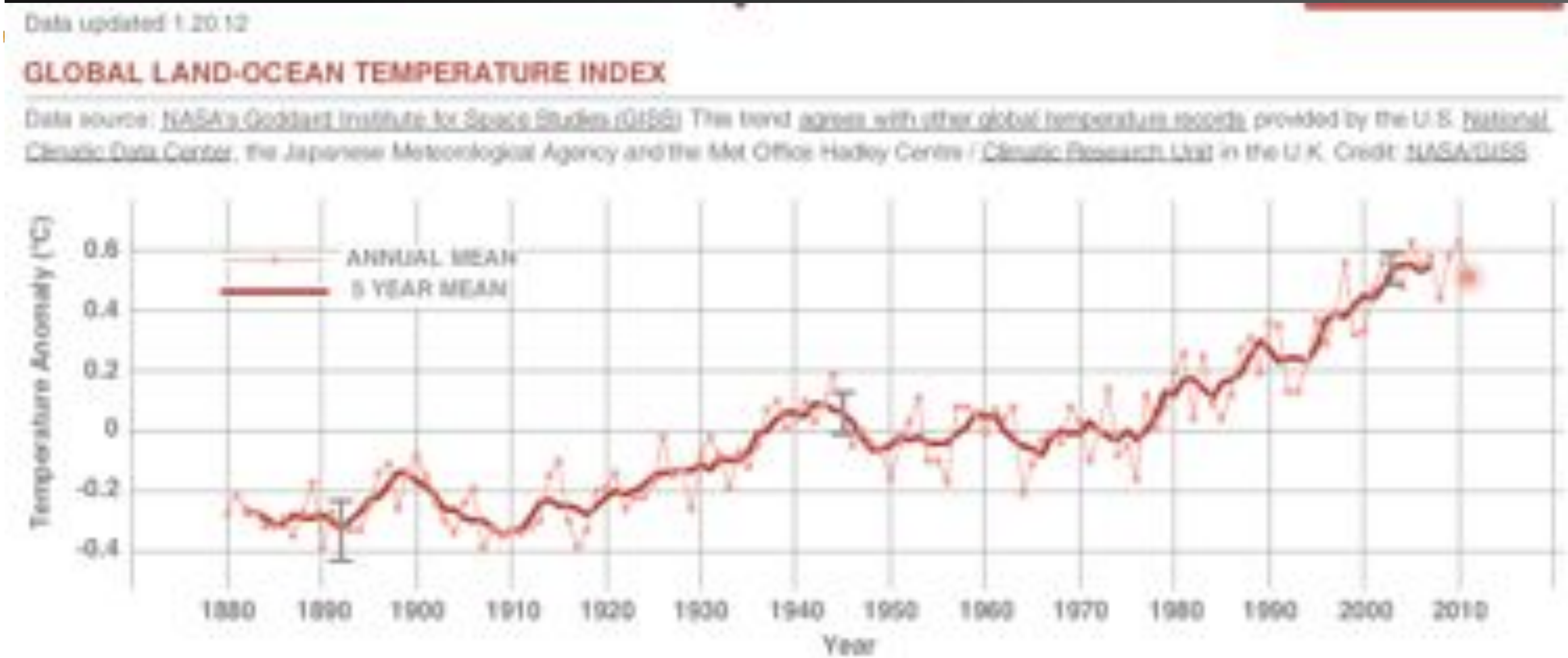
International and national scientific consensus on global change

- IPCC – Intergovernmental Panel on Climate Change
  - Latest (2007) report concludes: "**Warming of the climate system is unequivocal**, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."
- AGU – American Geophysical Union
  - 41,000 Earth and space scientists
  - "**Human activities are increasingly altering the Earth's climate**... Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures…"

Mounting evidence that the climate is already warming

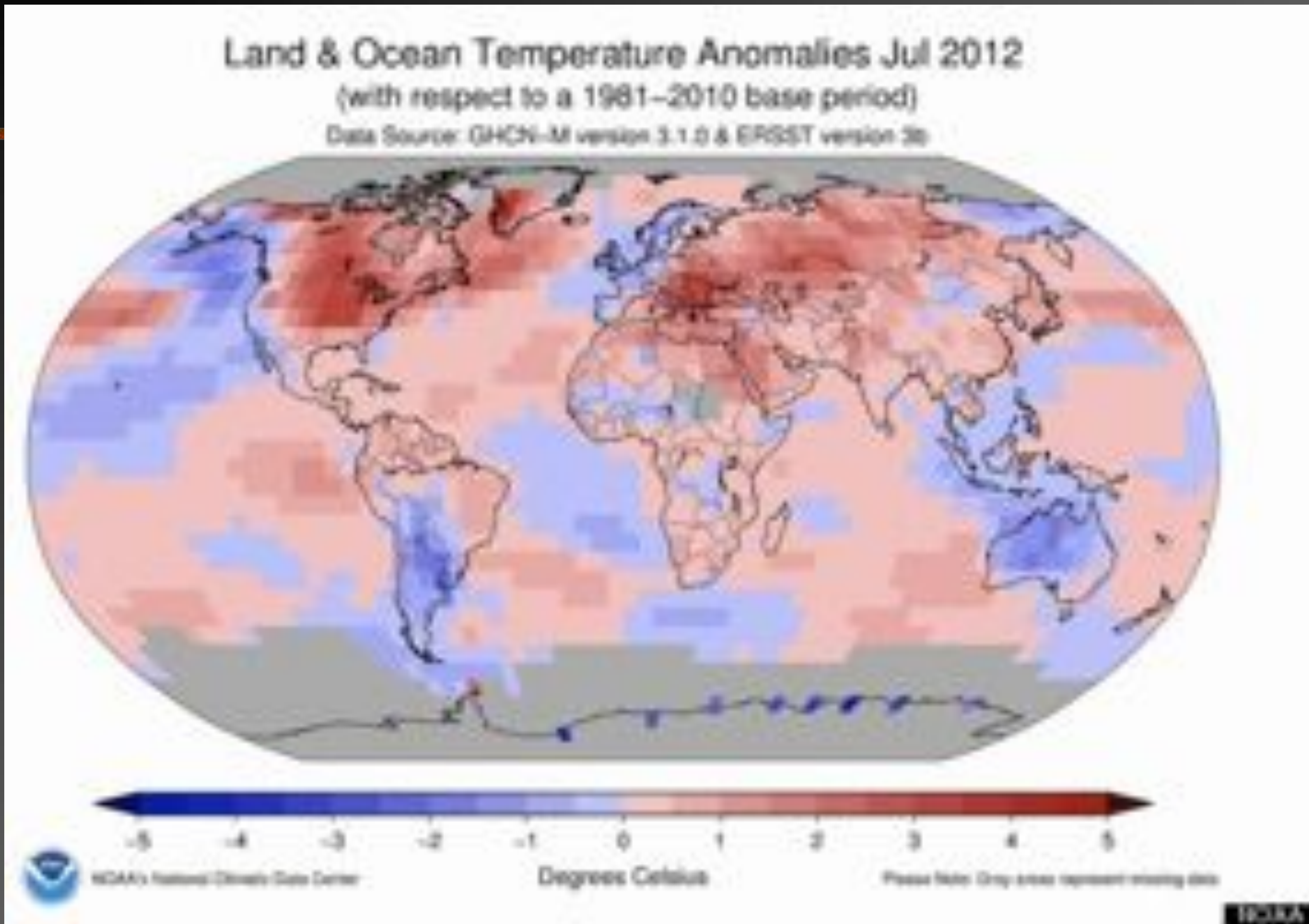
- First 8 months of 2012 hottest ever recorded (1 deg F warmer than record)
- 2000-09 was warmest decade on record
  - 1990s second warmest
- Arctic sea ice, Greenland land ice diminishing faster than expected
- Glaciers in retreat worldwide
- Antarctic ice shelves degrading

Long term temperature record (to 2011)

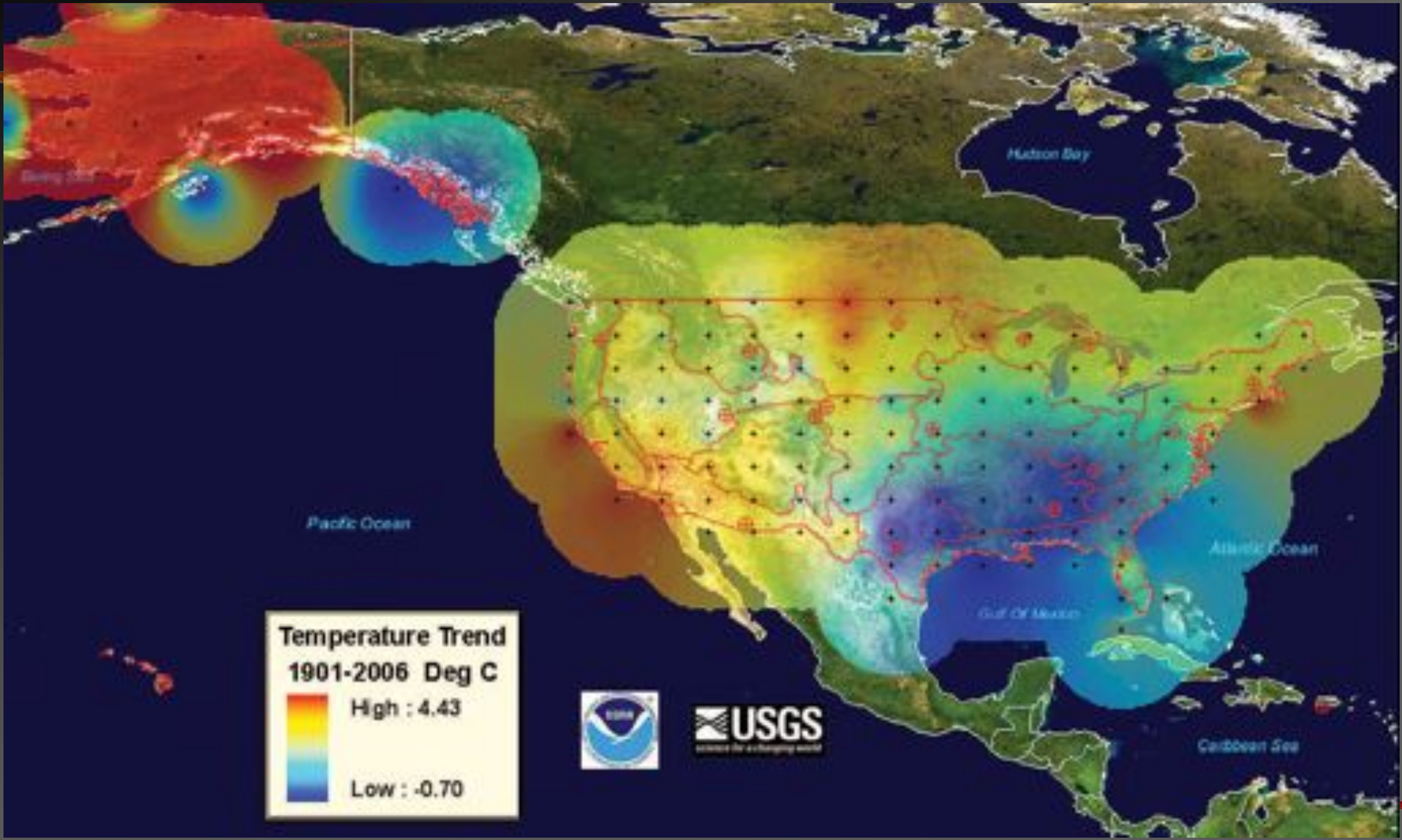


climate.nasa.gov/keyindicators/

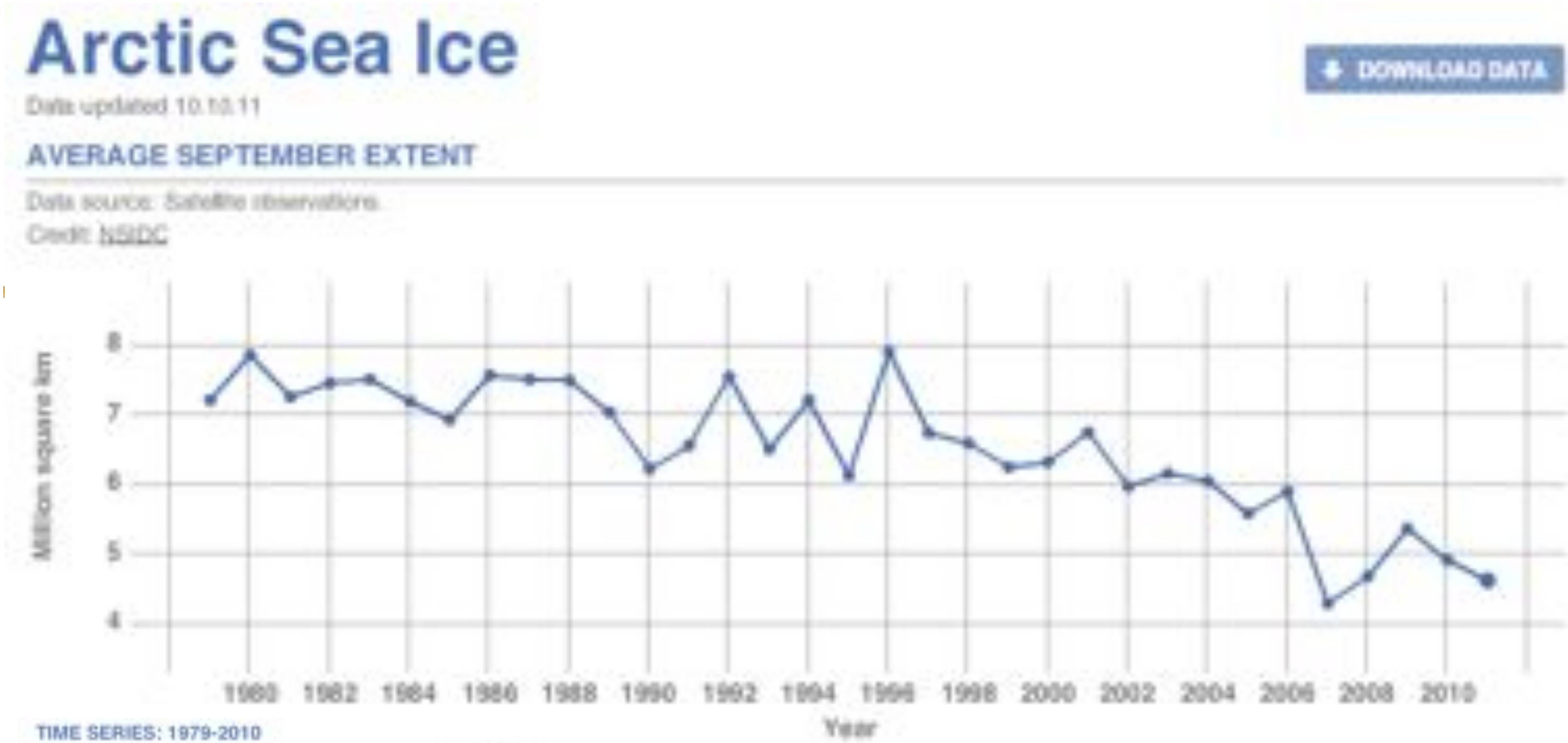
Warming is uneven



Uneven distribution of warming observed so far in the US



http://www.usda.gov/img/content/EffectsofClimateChangeonUSEcosystem.pdf



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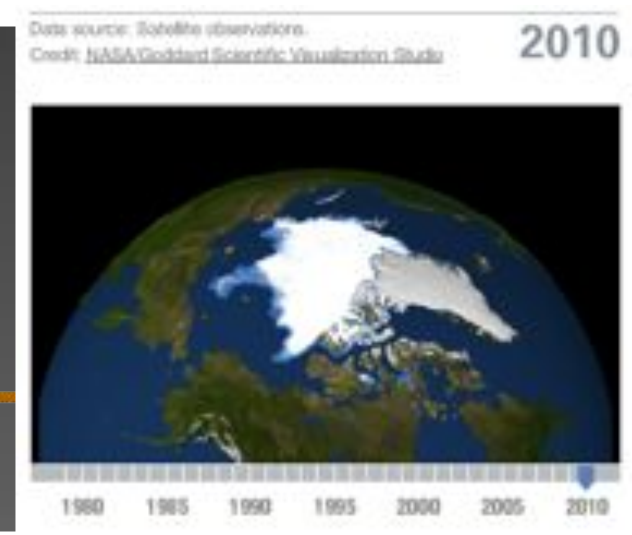

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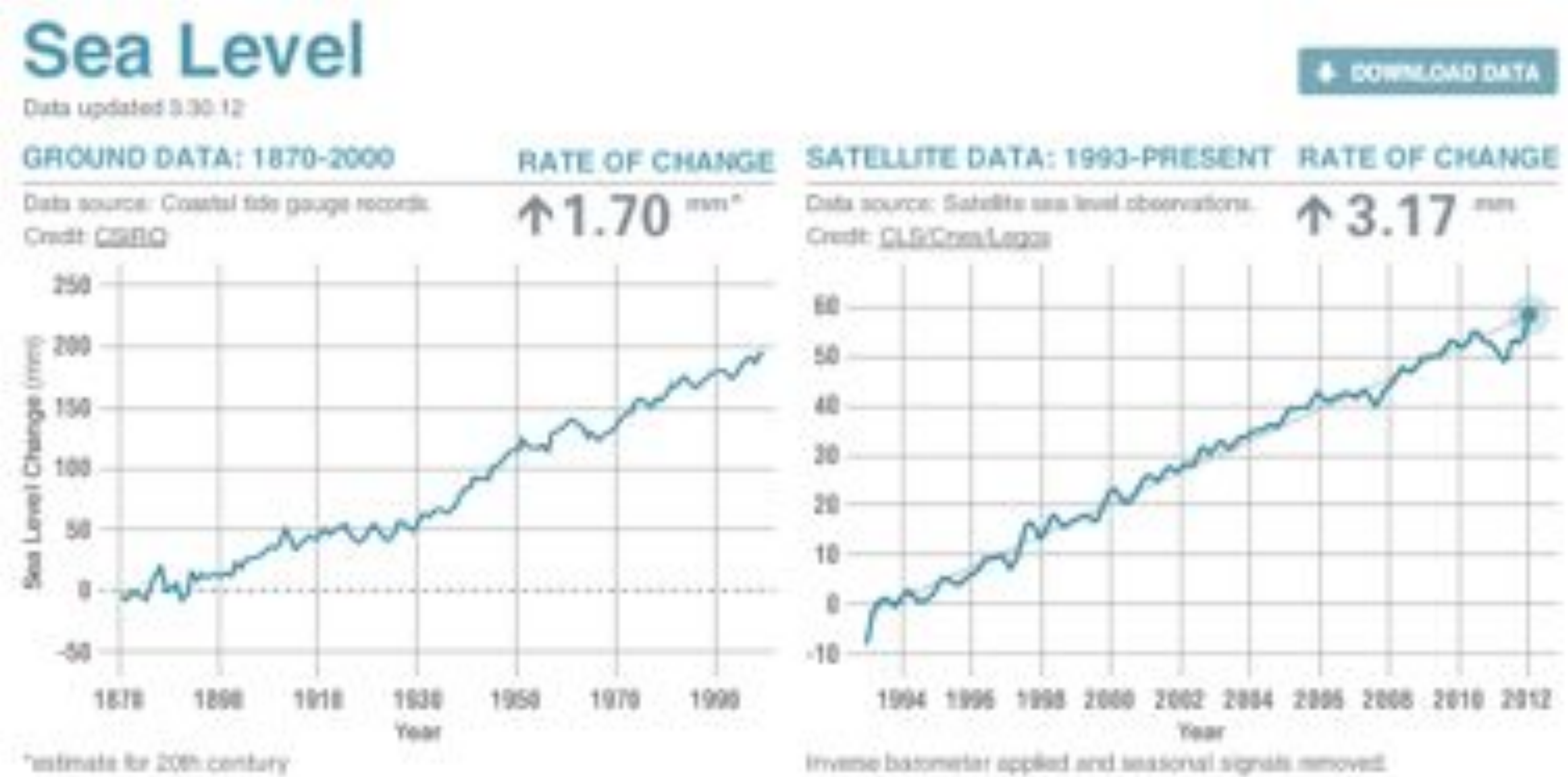
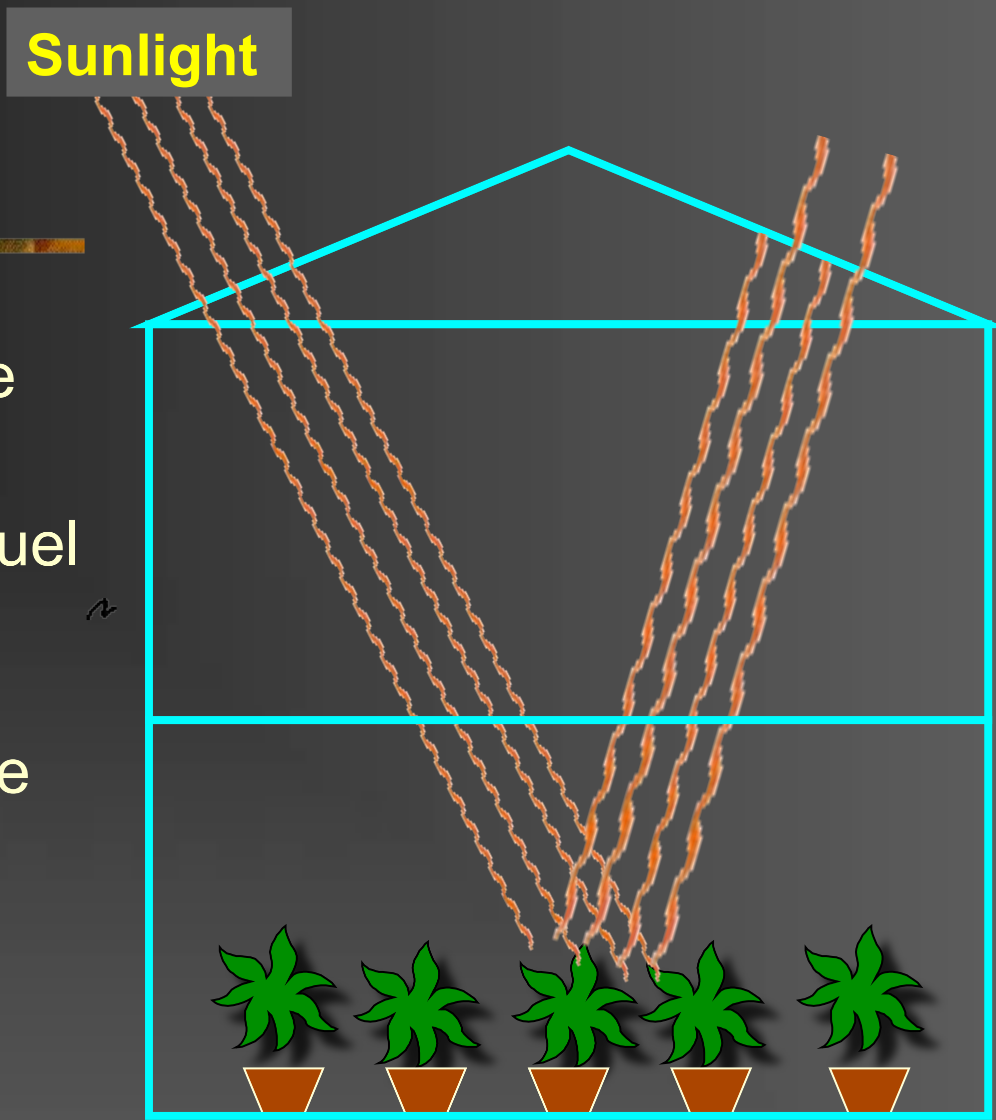
Historical sea level record



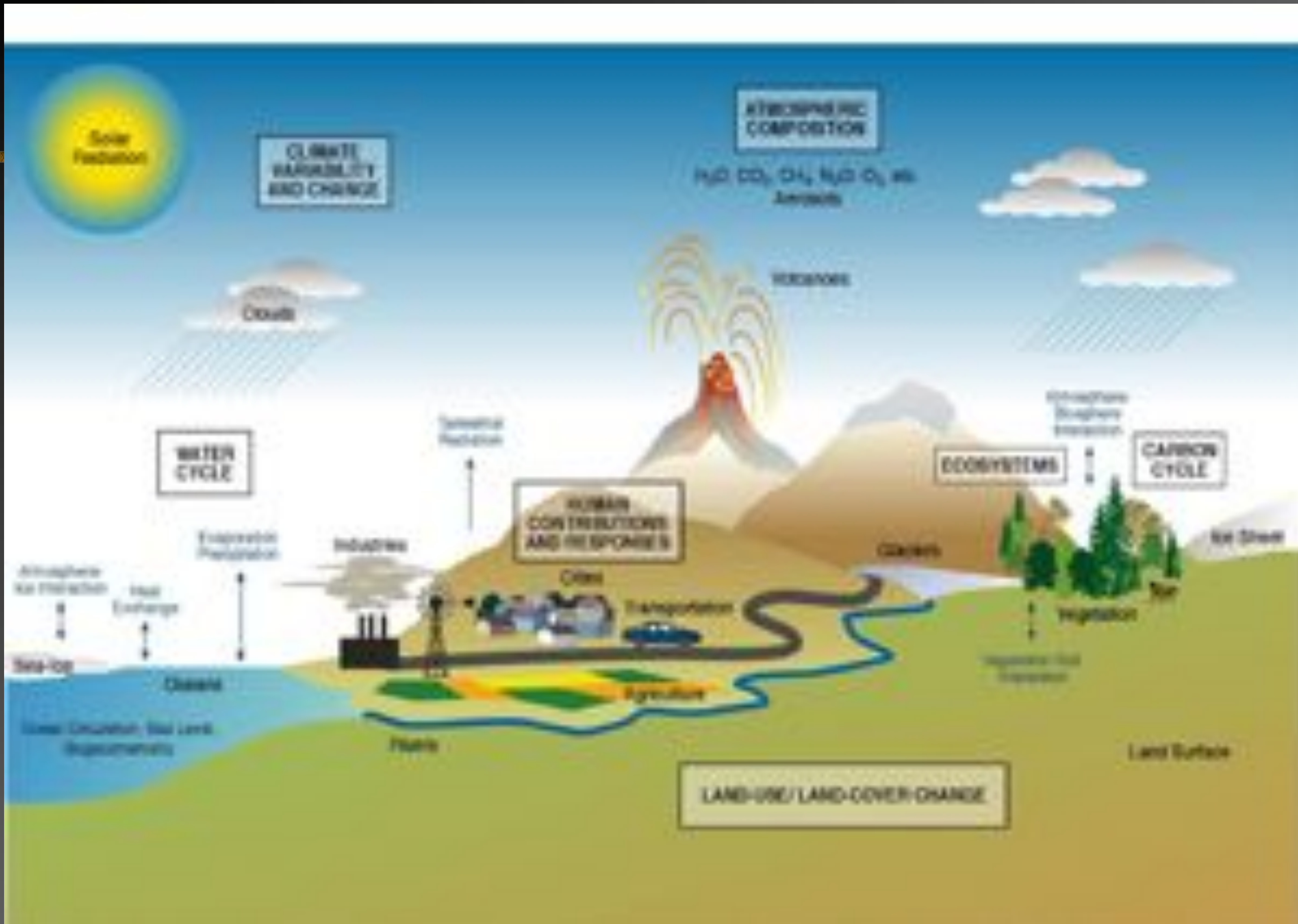
climate.nasa.gov/keyindicators/

The greenhouse effect

- Heat-trapping gases make the Earth's surface warm
- Human activities -- fossil fuel combustion, agriculture, deforestation -- increase heat-trapping "greenhouse gases"
  - Carbon dioxide, methane, nitrous oxide, ozone, CFCs
- Heat balance of the land surface also important

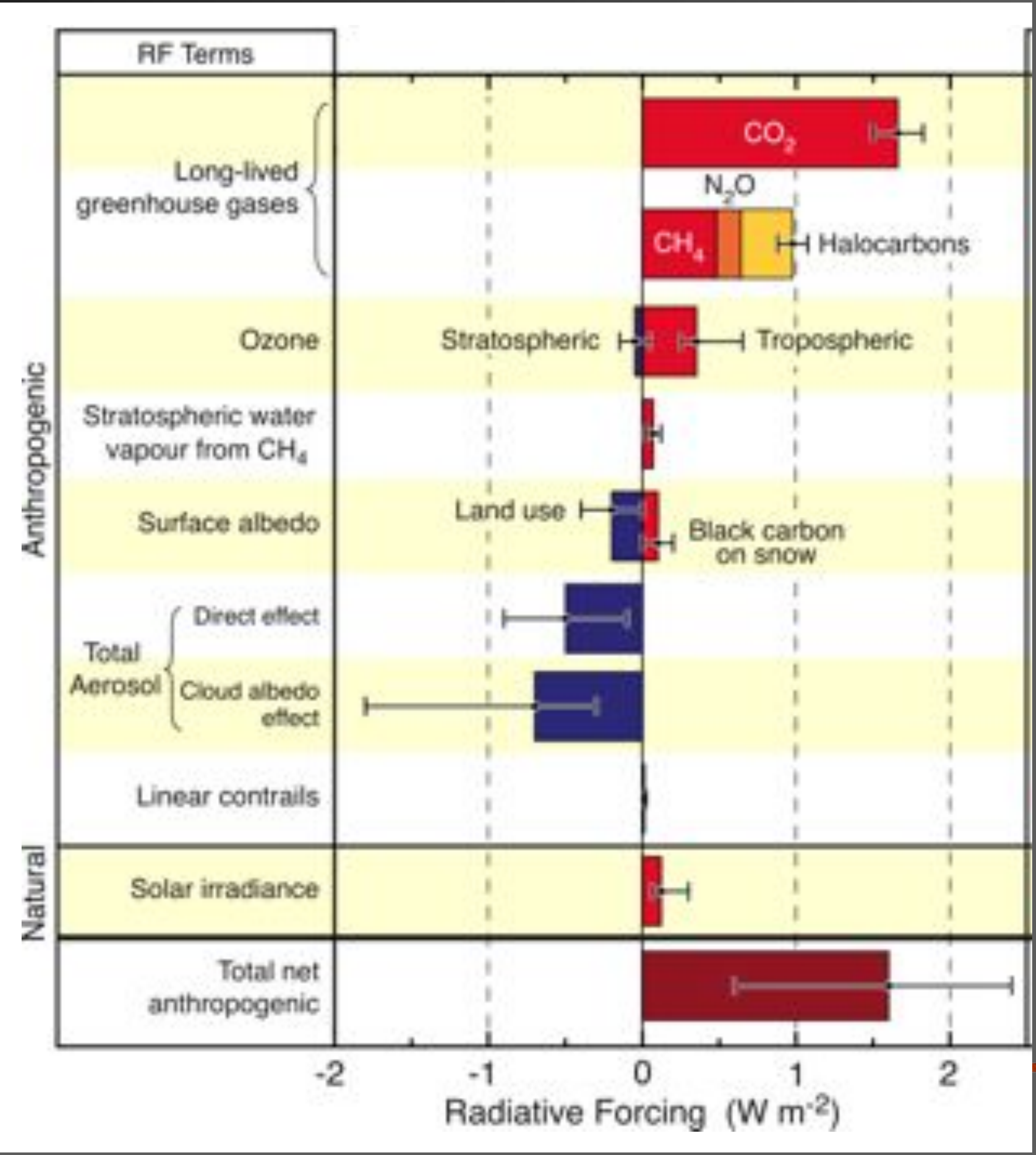


The global climate system is complex!



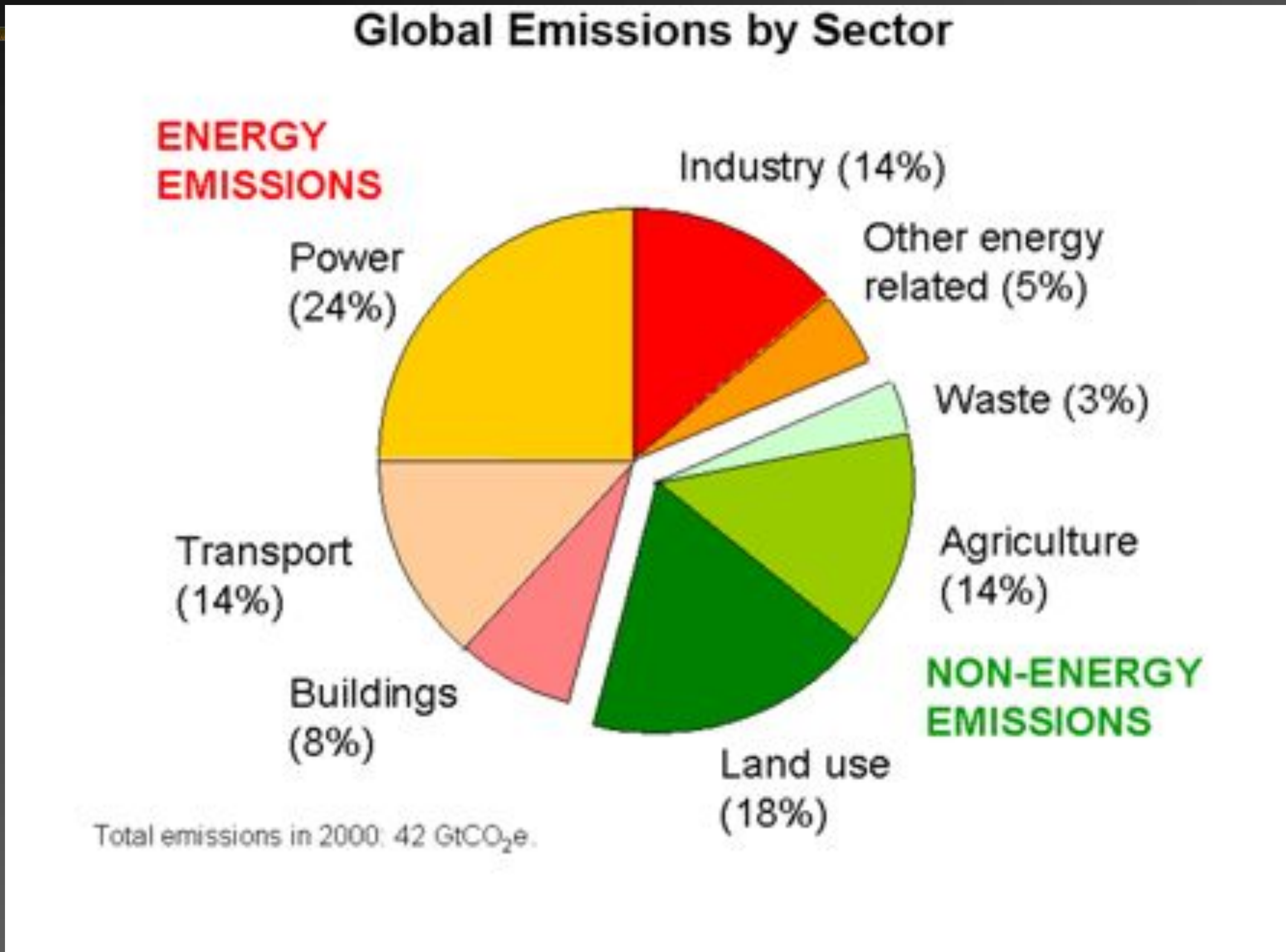
Radiative forcing

- Positive = heating
- Compensating effects
- Net result = heating
- Note uncertainties (error bars)

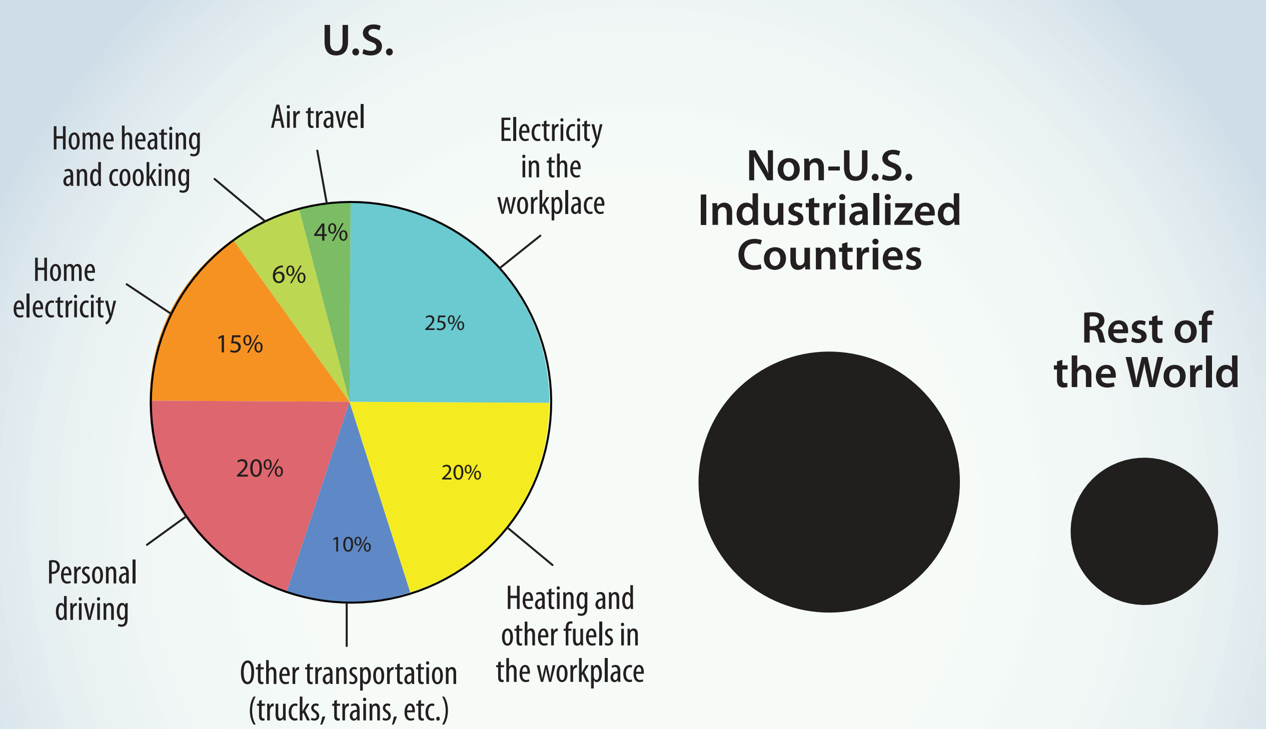


IPCC 2007

Diverse activities cause climate change



Fossil fuel contributions



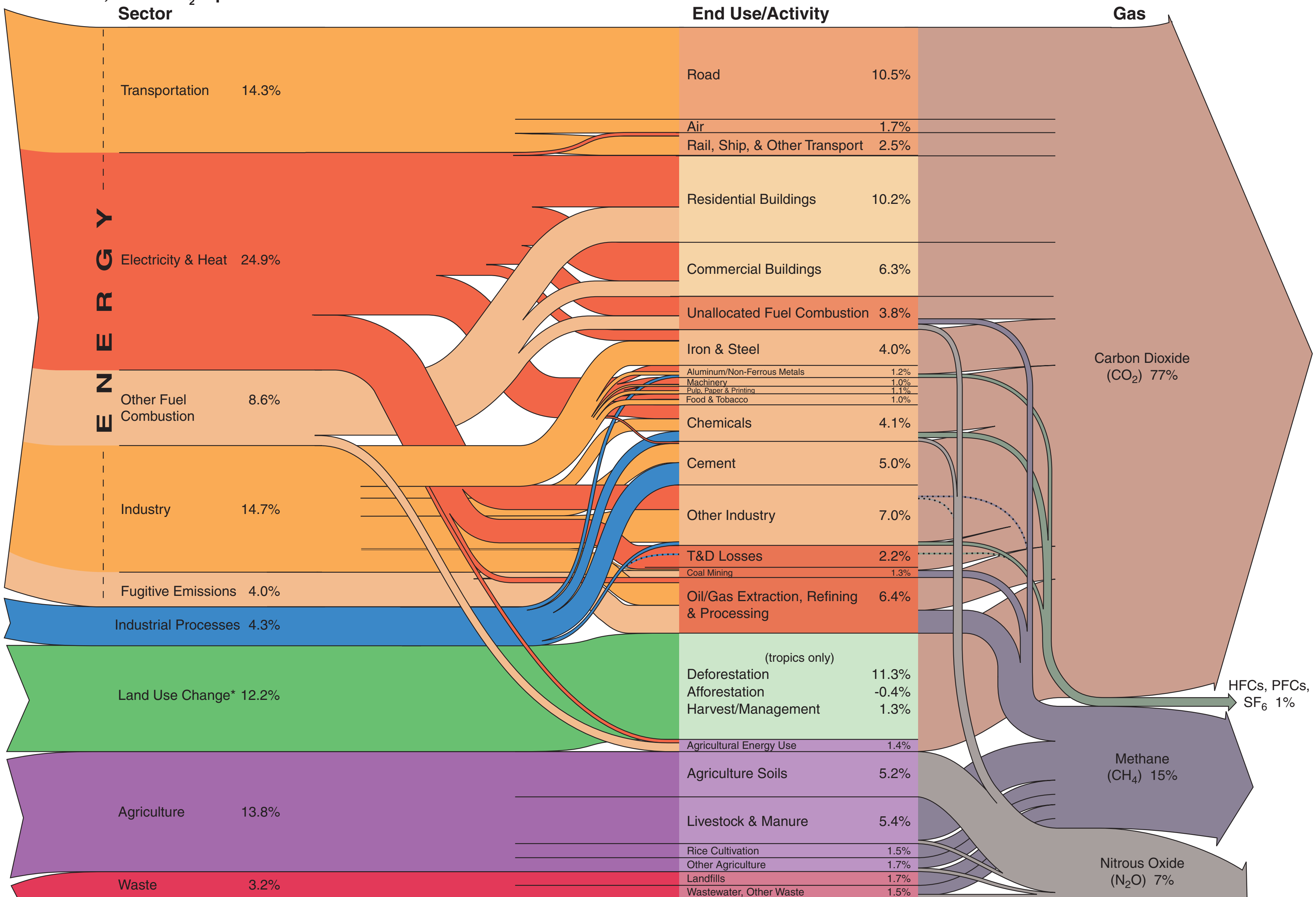
	U.S.	Non-U.S. Industrialized Countries	Rest of the World
	19.9 metric tons of CO_2 per person per year	**8.4** metric tons of CO_2 per person per year	**2.7** metric tons of CO_2 per person per year
POPULATION	0.3 billion (5% of world)	0.9 billion (12% of world)	5.3 billion (82% of world)
CO_2 EMISSIONS (TONS)	5.9 billion (21% of world)	7.3 billion (27% of world)	14.3 billion (5.2% of world)

Average Per-Capita CO_2 Emissions from Fossil Fuels in 2005 The U.S. emits lots more carbon per person than the rest of the world; it also emits more than other developed countries.

From "Twenty questions and answers about climate change" (Sally Ride Science and Climate Central, 2010)

World Resources Institute: http://pdf.wri.org/world_greenhouse_gas_emissions_2005_chart.pdf

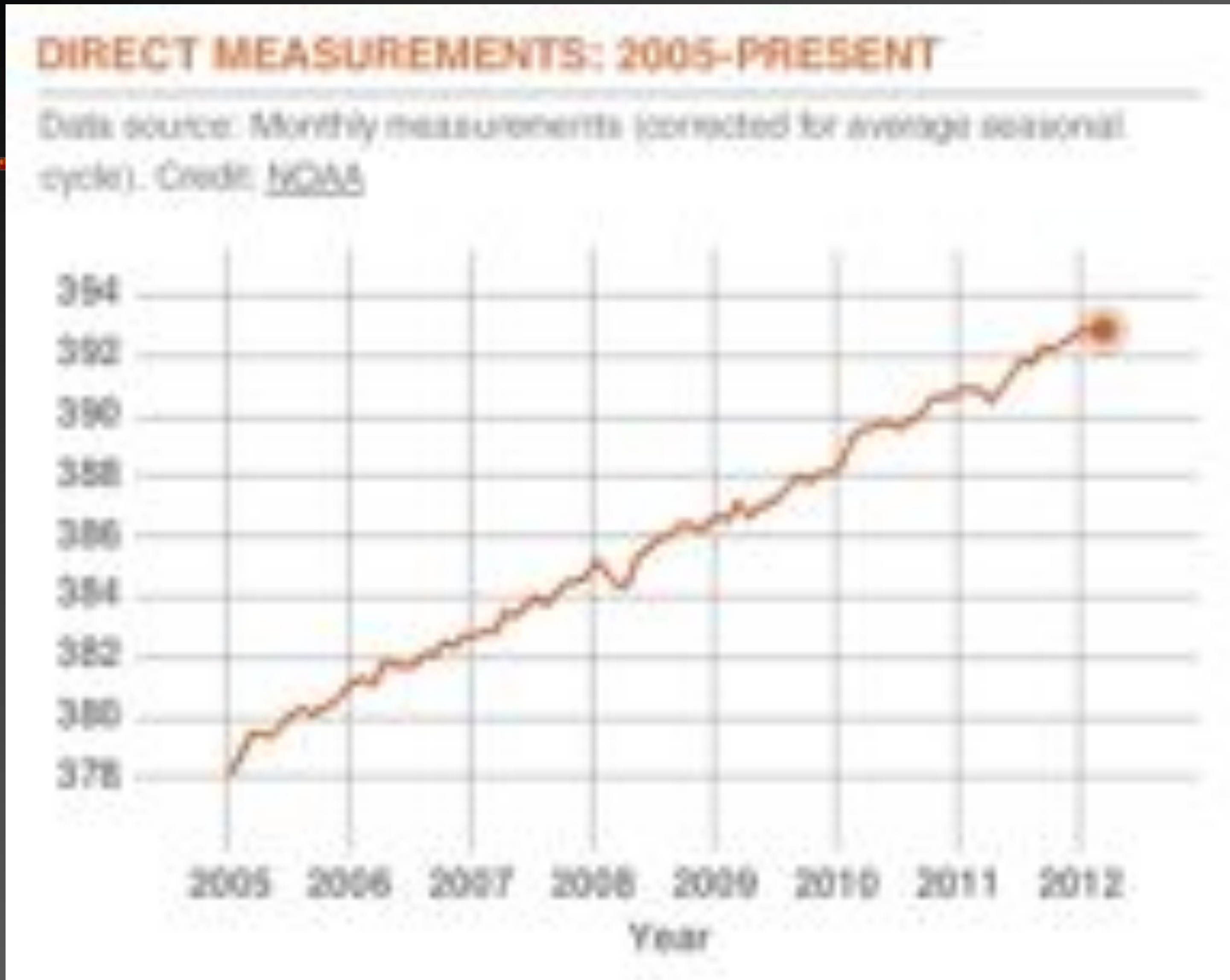
World Greenhouse Gas Emissions in 2005
Total: 44,153 $MtCO_2$ eq.



Sources & Notes: All data are for 2005. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 44,153 $MtCO_2$ equivalent. See Appendix 2 of *Navigating the Numbers: Greenhouse Gas Data & International Climate Policy* (WRI, 2005) for a detailed description of sector and end use/activity definitions, as well as data sources. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

* Land Use Change includes both emissions and absorptions, and is based on analysis that uses revised methodologies compared to previous versions of this chart. These data are subject to significant uncertainties.

Recent carbon dioxide record



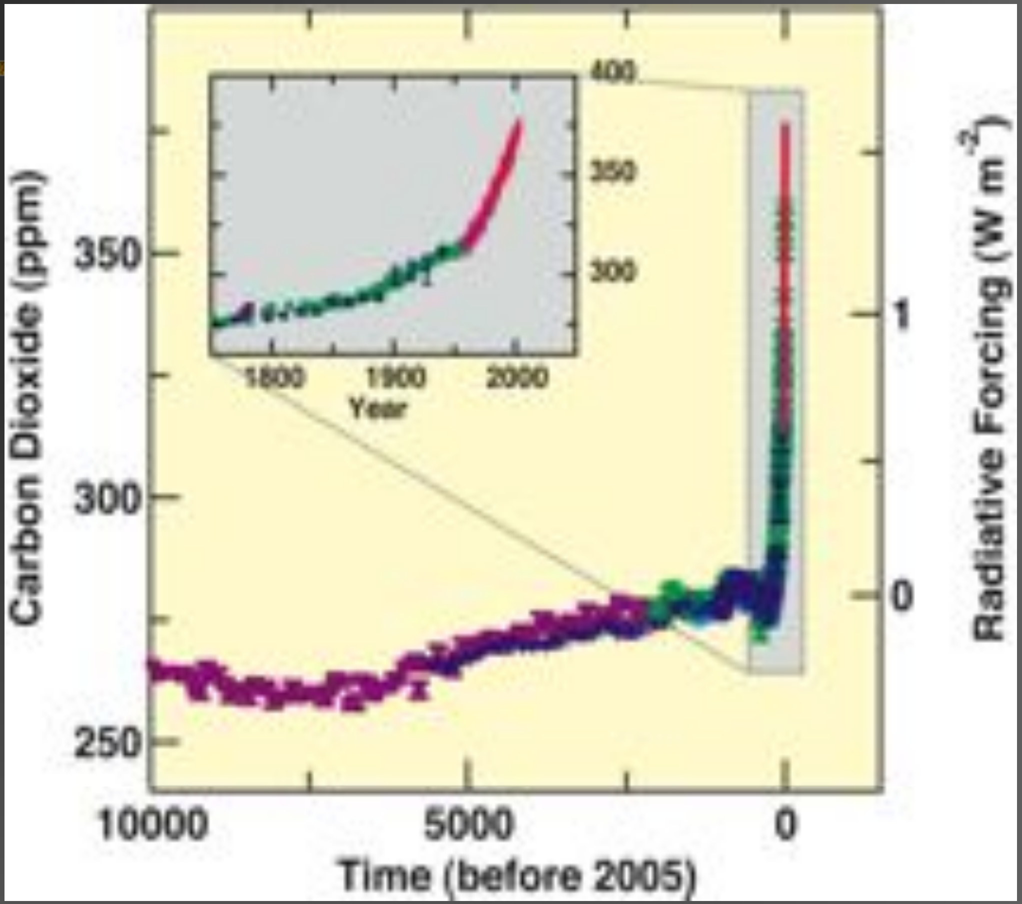
climate.nasa.gov/keyindicators/

Long-term carbon dioxide record

climate.nasa.gov/keyindicators/

Atmospheric carbon dioxide increase

- Combustion of fossil fuels is main source
- Land use change, causing reduction in organic carbon stocks, is also important
- Accounts for ~70% of greenhouse forcing to date

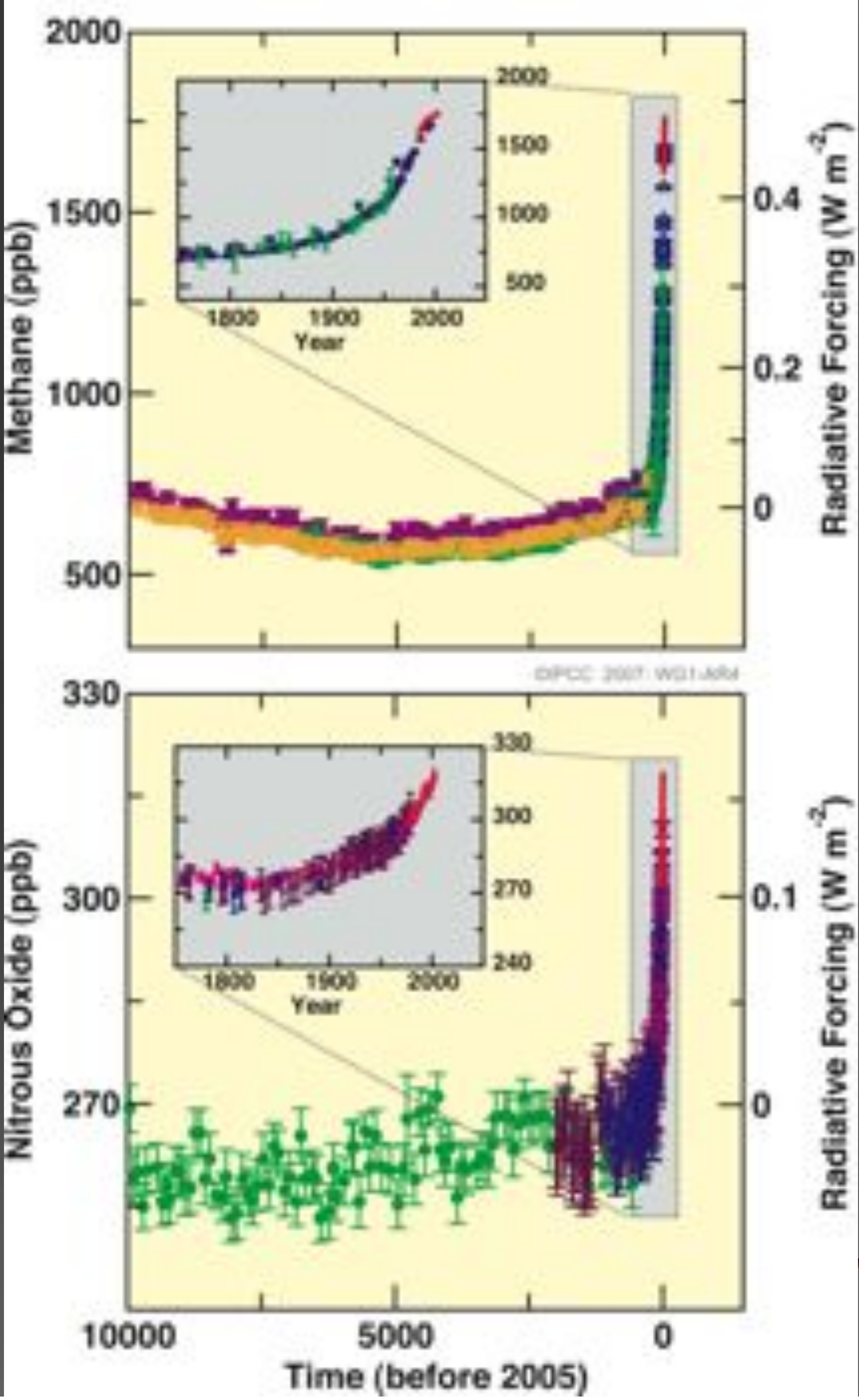


IPCC (2007)

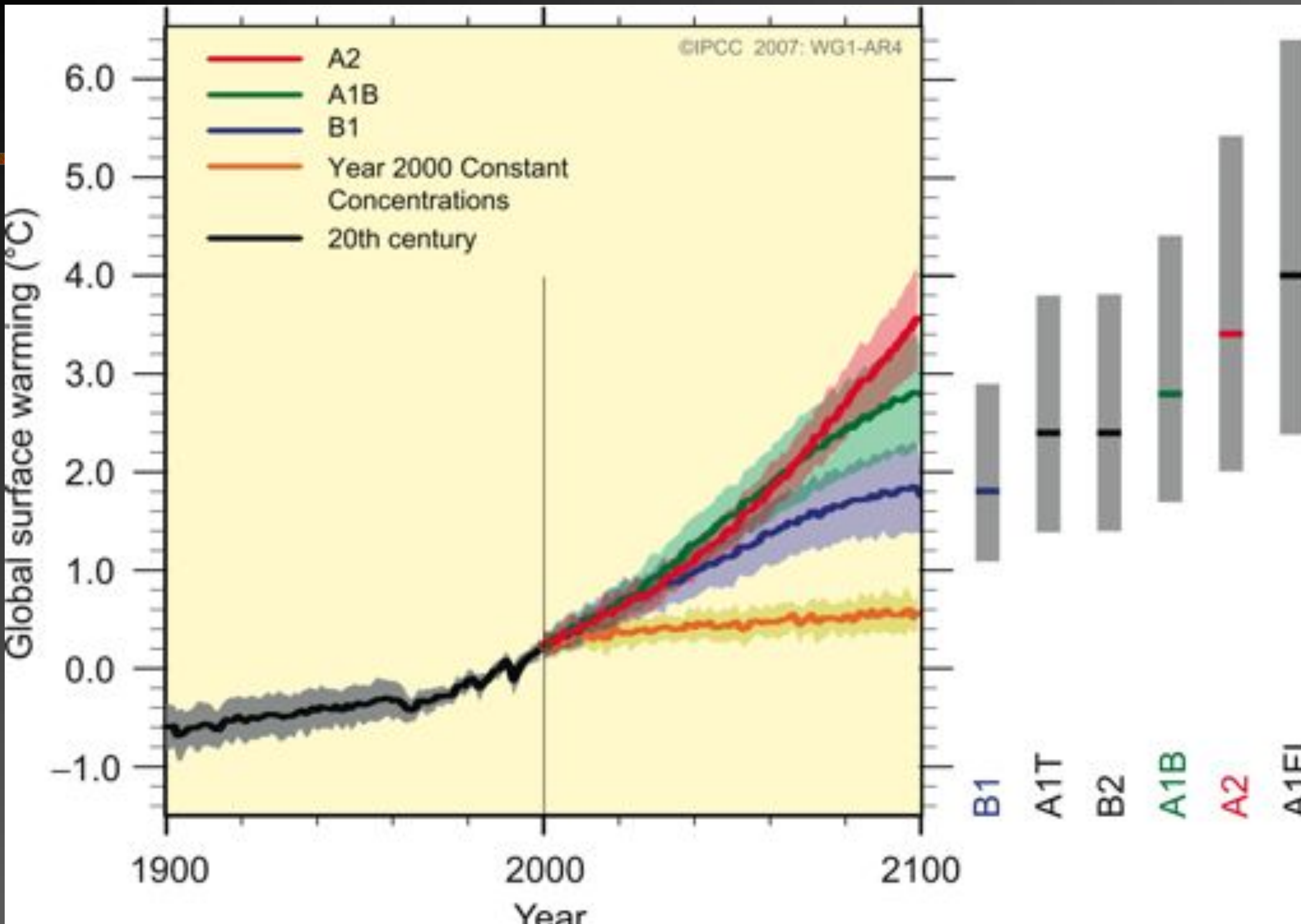
Atmospheric methane, nitrous oxide increases

- Methane mainly from rice paddies, ruminant livestock, natural gas, landfills
- Nitrous oxide mainly from agriculture
- Rates of increase are greater than carbon dioxide
- Both are more potent greenhouse gases

IPCC (2007)



Global climate projections



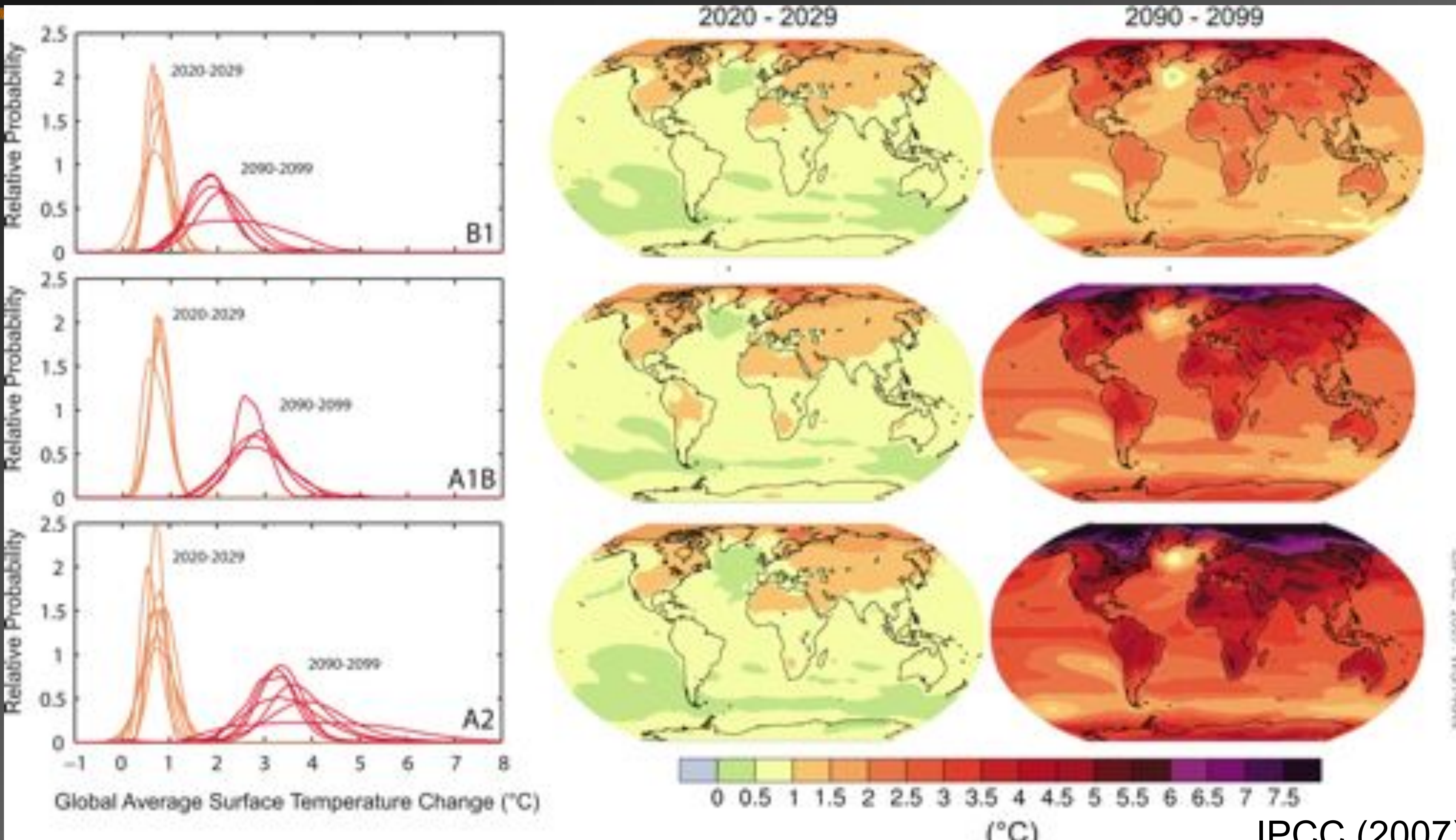
IPCC (2007)

Does this projected temperature change matter?

- Global average temperatures could increase from 4-7°F
  - The difference between the Ice Age and now was only 9-11°F!
- Rate of warming will be faster than at any time in the past 10,000 years
- High latitudes including Great Lakes region will warm more
- Arctic warming may exceed range over the past *million* years

IPCC (2007); UCS/ESA (2003); Houghton (2004)

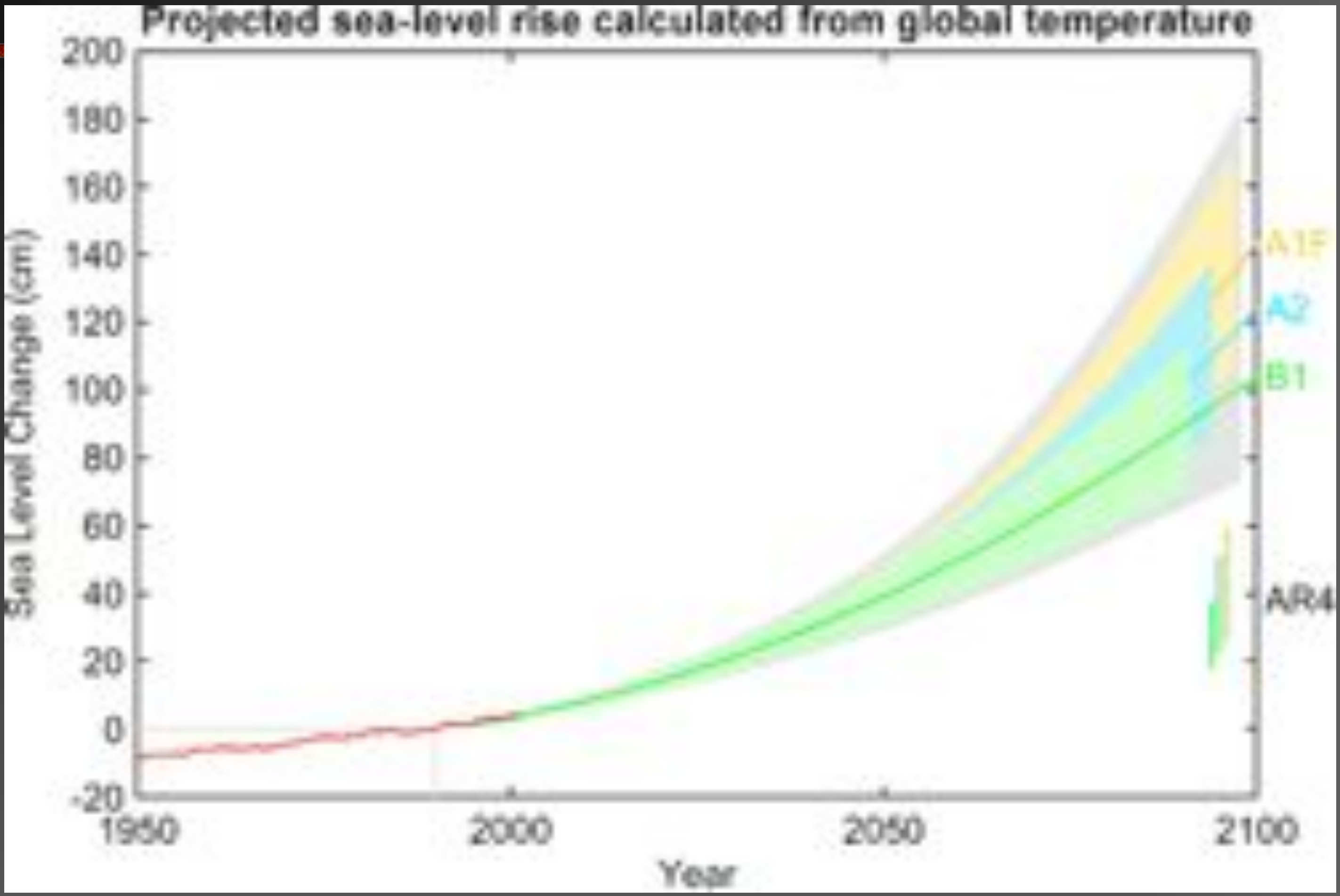
Future warming will be unevenly distributed



IPCC (2007)

Projected rise in sea level

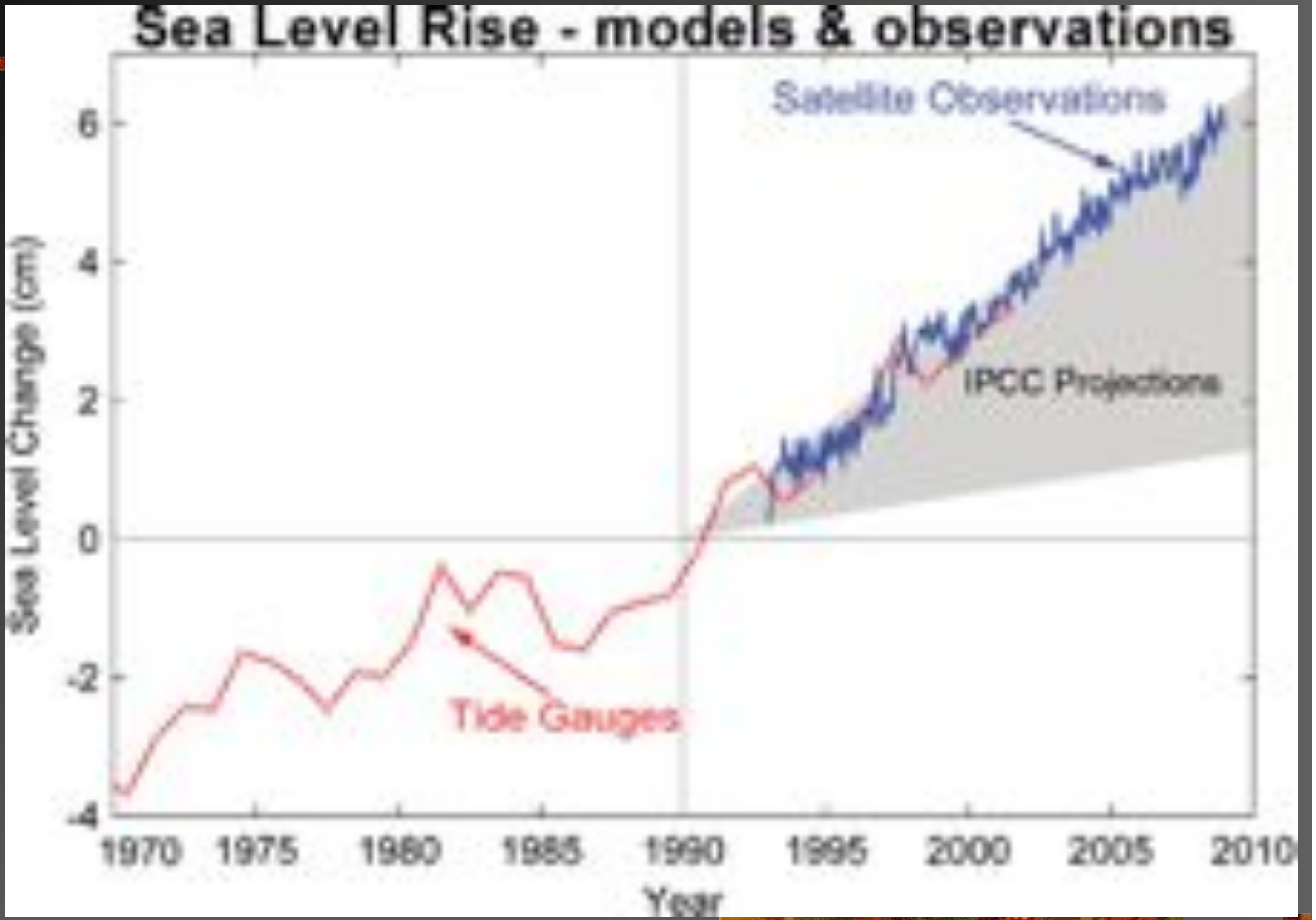
- Already increased ~20 cm (8 inches)
- Thermal expansion, glacier melting
- Delay to equilibrate



IPCC (2007) data; chart from skepticalscience.com

Recent rise in sea level vs. projections

- Our models may be too conservative



IPCC (2007) and Allison et al. (2009) data; chart from skepticalscience.com

Sea level rise and coastal ecosystems

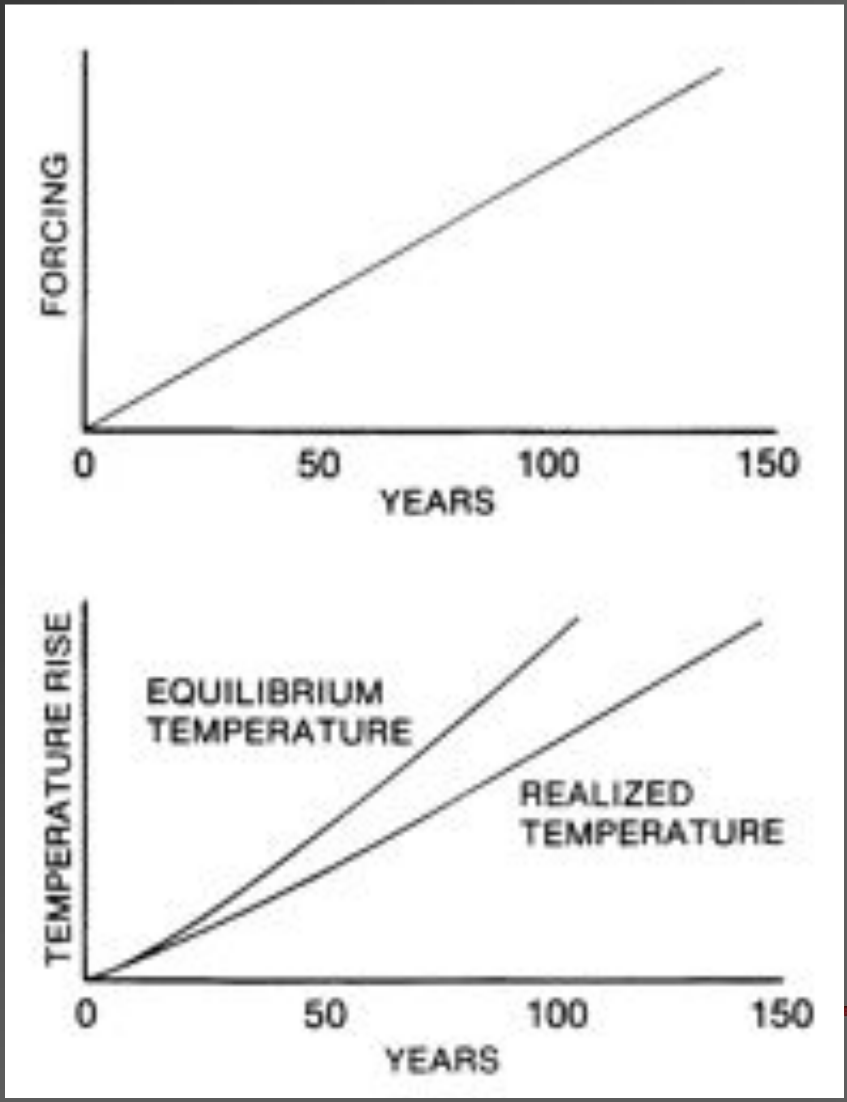
- IPCC (2007) sea level projections do not account for possibility of massive loss of land ice
- 6 m rise is possible with loss of much of the susceptible ice in either Greenland or Antarctica

Fig. 1. Spatial extent of 1- and 6-m potential future sea-level rise along the East and Gulf coasts of the United States and for selected major coastal municipalities. Elevation and connectivity to the ocean determine sea-level rise extent. Proportion of land area within municipalities coincident with sea-level rise extent determines percentage of susceptible area. The U.S. Geological Survey and Census Bureau provided elevation and municipality boundary data, respectively.

Overpeck and Weiss 2009

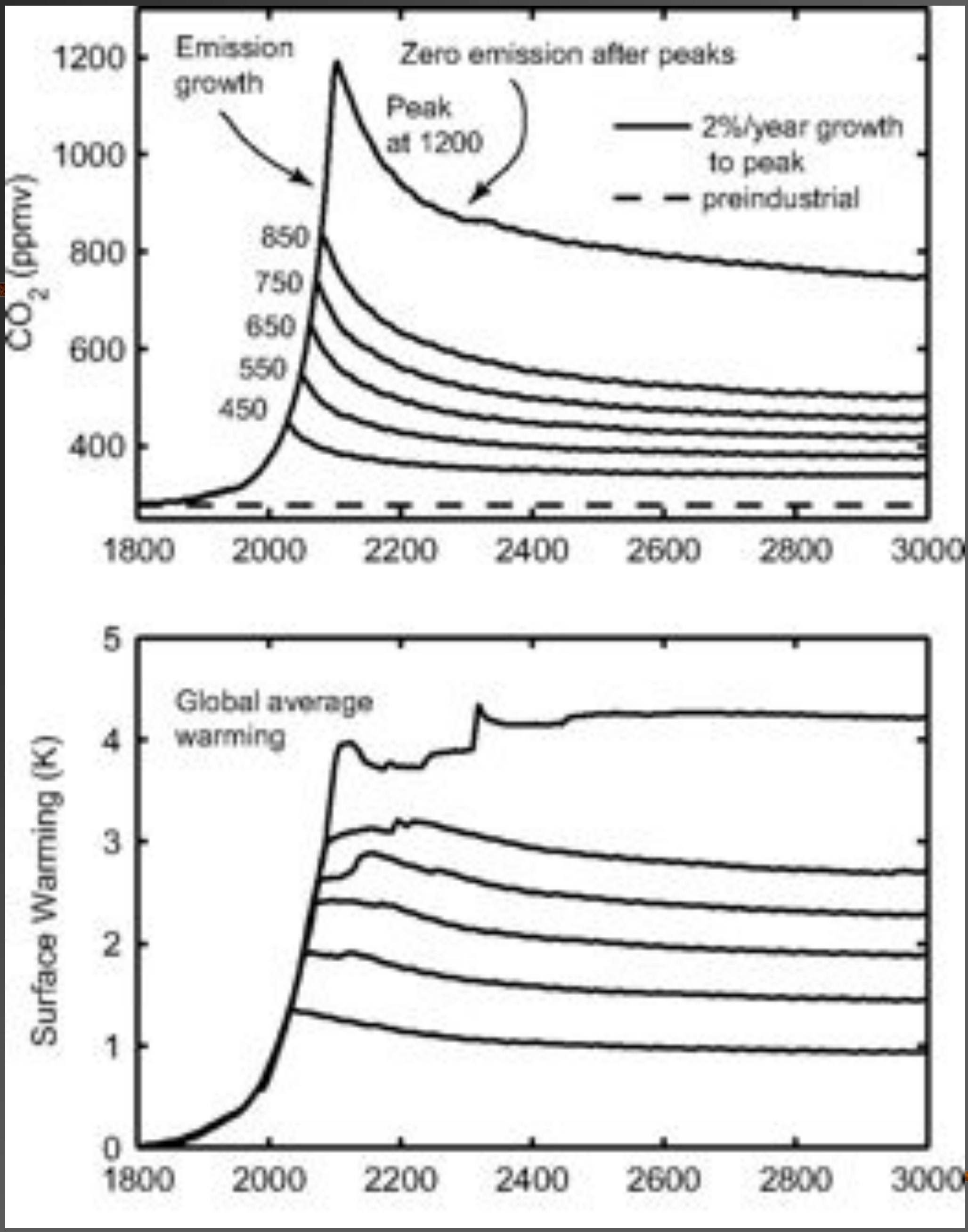
We're already committed to a warmer world

- Impacts of greenhouse gases are long-lasting
- Oceans delay to warm
- Even with immediate stabilization of greenhouse gas emissions, warming would continue for decades



Our irreversible commitment to climate change

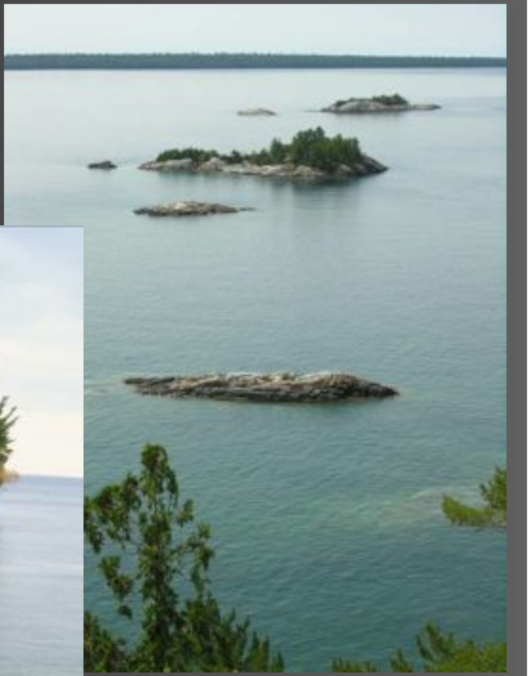
- Models illustrate what would happen if emissions ceased after reaching certain peaks
- Long lifetime of CO_2 plus ocean heat exchange largely explain these results



Solomon S et al. PNAS 2009;106:1704-1709

Projections for the Great Lakes region

- All models agree on warming
- Specific details are more uncertain at regional to local scales
- Most likely:
  - Wetter winters and springs
  - Warmer nighttime temperatures
  - Less snow and ice
  - More extreme weather



Migrating climate

Michigan's Climate Migrates South

Changes in average summer "heat index"—a measure of how hot it actually feels based on a specific combination of temperature and humidity—could strongly affect Midwesterners' quality of life in the future. For example, the red outlines track what summers in Michigan could feel like over the course of the century under the higher-emissions scenario; the yellow outlines track what summers could feel like under the lower-emissions scenario.

Extreme weather more common?

- New studies show greater probability ("loaded dice" analogy)
  - Heavy precipitation
  - Droughts
  - Damaging storm events
  - Hurricanes?
- Still cannot attribute a particular event to climate change
  - Only its probability

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DROUGHT FORCES SOUTHWEST MICHIGAN FARMERS TO TAP RIVERS, CREEKS, PONDS IN FIGHT TO SAVE CROPS

"This is the worst it's ever been, and we've lived here 45 years."

"Our sole source of livelihood is pumping water from that creek."

Ecosystem impacts of global change

- Massive changes in ecosystems are possible, such as:
  - Distributions of plants and animals
  - Loss of entire ecosystems (e.g., coral reefs, montane rain forests)
  - Activity of pests and pathogens (e.g., bark beetles)
- Magnitude and rate of change are important, as are interactions with human activities

Ecosystem feedbacks and global climate change?

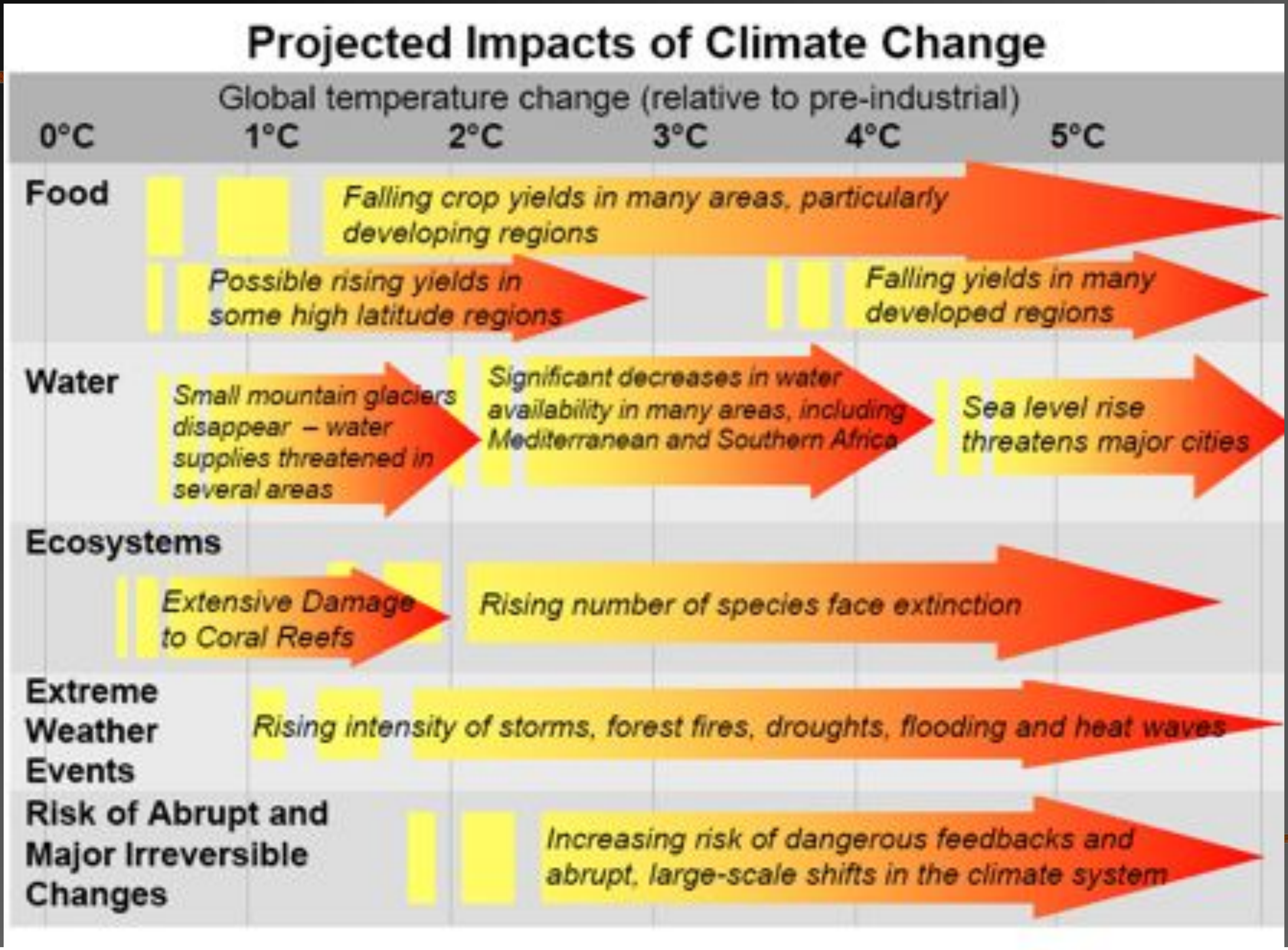
- Ecological feedbacks could potentially alter the course of global environmental change, but remain poorly understood.
- Examples:
  - The CO_2 fertilization effect on forests (reduces climate change)
  - Higher temperatures may stimulate respiration rates more than photosynthetic rates (enhances climate change)
  - Higher temperatures may stimulate methane production in high-latitude wetlands (enhances climate change)
  - Human activities in response to ecosystem changes (??)

Will humanity succeed in stemming the rate of climate change?

- Kyoto agreement as an example of the political challenges that lie ahead
- The war for public opinion
  - Role of special interest groups
- Rising likelihood of action => rising resistance to defend the status quo

Is climate stabilization too costly?

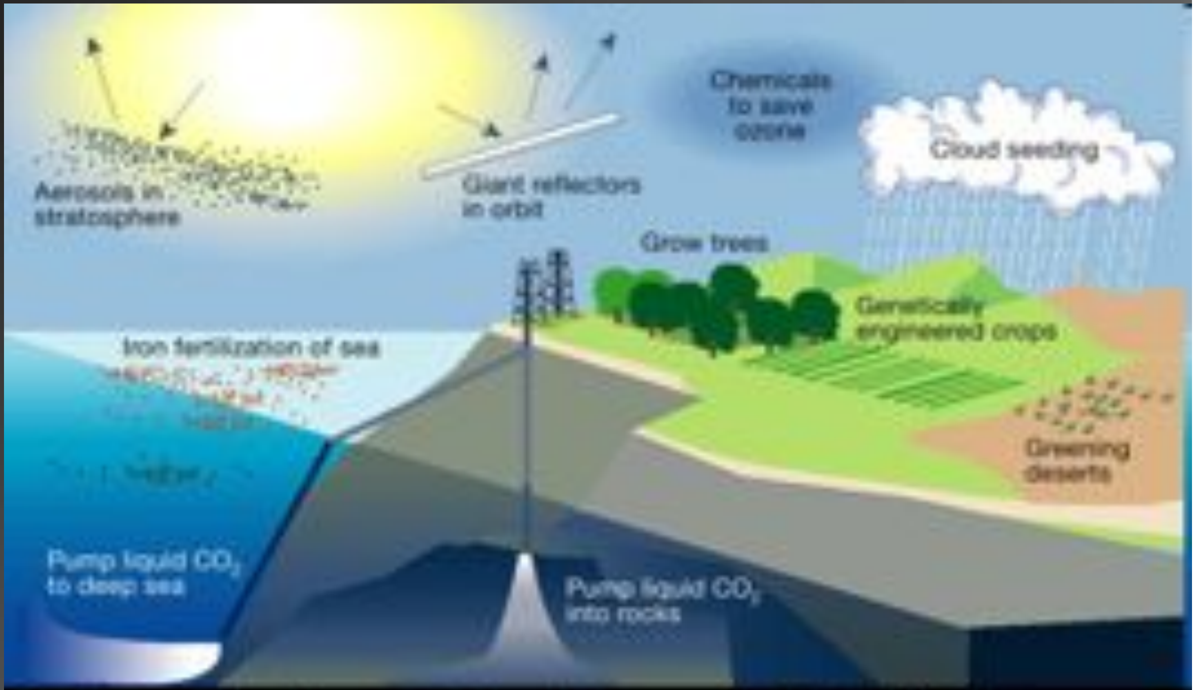
(If yes, for whom and over what timescale??)



See more detailed figure in IPCC 2007 Summary for Policy-makers

Geoengineering: Technology to the rescue?

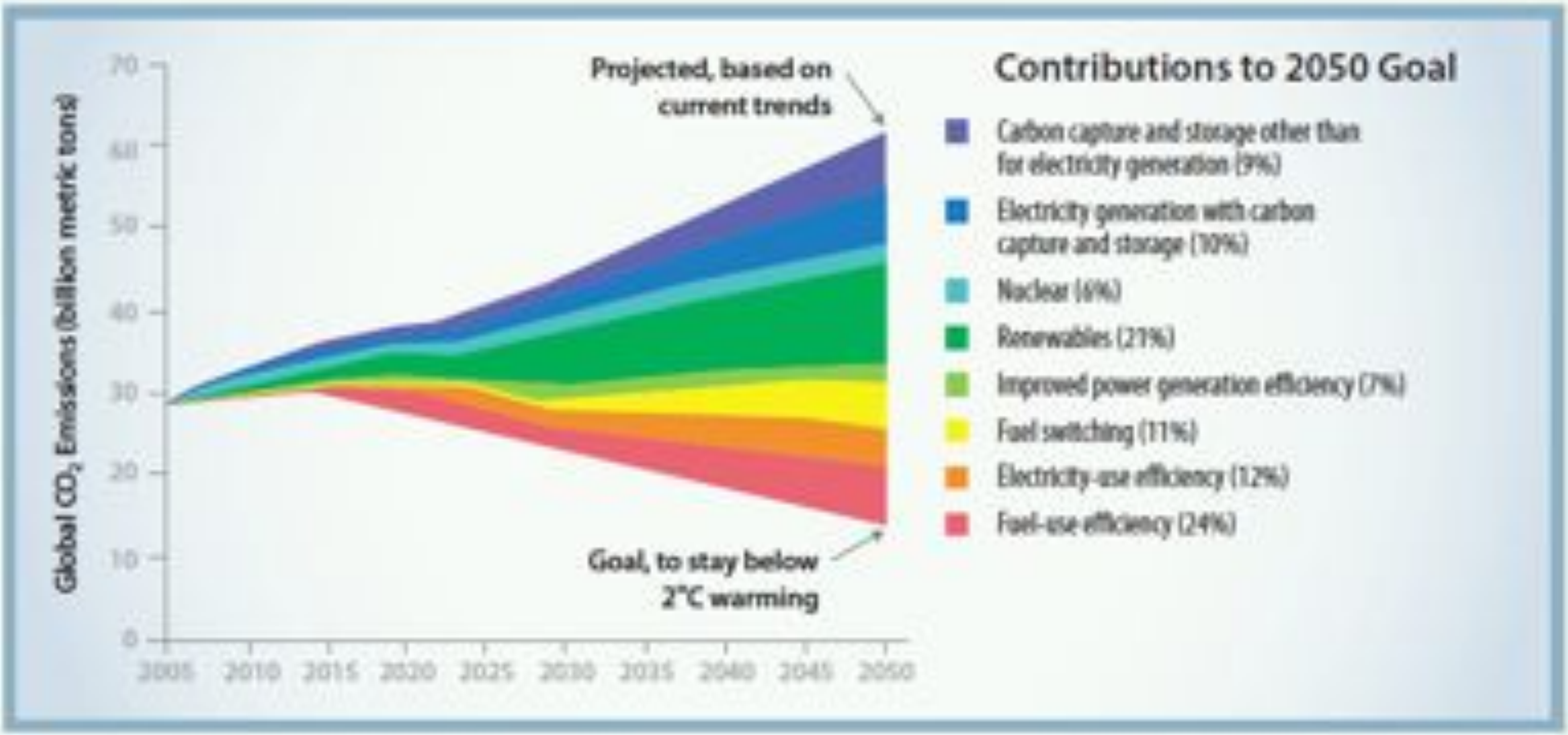
- No geoengineering method "can provide an easy or readily acceptable alternative solution..." (Royal Society of London, 2009)
- Yet we should be studying options in case we need them!



Schematic representation of various climate-engineering proposals (courtesy B. Matthews).

http://iis-db.stanford.edu/news/1881/gallery/actual/1881-small_geoengineering_scenarios.jpg

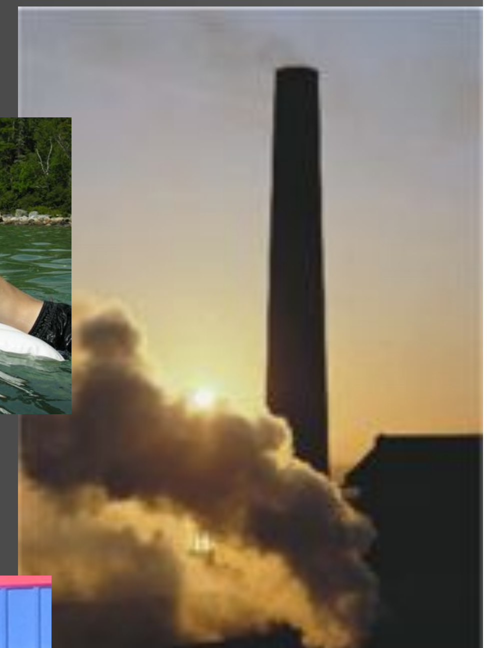
A suite of solutions is the best choice



From "Twenty questions and answers about climate change" (Sally Ride Science and Climate Central, 2010)

"What kind of world will our grandchildren inherit?"

- We can moderate the pace and severity of climate change!
- Stabilization of greenhouse gas emissions is a start
- *Reductions* are imperative in the long term
- No single silver bullet…
  - Conserve
  - Invent
  - Mitigate
  - Adapt



Professors, graduate students, and K-12 teachers all have important roles

- Educate yourself on the subject!
- If challenged, seek help!
- Scientists of all fields are trained to recognize and seek out reliable sources of information
- We would be remiss in our duty if we ignore or downplay global change…